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MONTHLY NOTICES

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H. J. Gibson, Esq., Junior St. James's Club, St. James's Street, S.W.

Capt. George Richard Stevens, F.R.G.S., 12 Abingdon Villas, Kensington, W.; and

John Fletcher Moulton, M.A., of Christ's College, Cambridge, were balloted for and duly elected Fellows of the Society.

Mr. John Williams, Assistant Secretary of the Society, died on the 3rd of December 1874, in his 78th year. The following Resolution was passed at the Meeting of the Council:—

Resolved that—

> The Secretaries be requested to communicate to the Eldest Son of the late Mr. John Williams the deep sympathy felt by the Council in the bereavement which he and the other members of his family have just experienced; and at the same time to express the high appreciation of the Council of the moral worth and zealous services of their late Assistant Secretary in the discharge of his duties during the long period of twenty-eight years for which he was connected with the Society.

On certain Phenomena presented by the Shadows of the Satellites of Jupiter while in Transit; and on a possible Method of deducing the Depth of the Planet's Atmosphere from such Observations. By C. E. Burton, Esq.

Several observers of eminence have recorded, on different occasions, various anomalous appearances presented by the shadows of the satellites of *Jupiter* when in transit over his disk. From these records I have selected two, which describe appearances seemingly not very diverse in character from those hereafter to be mentioned.

The first of these is due to the late Sir J. South, who, with two telescopes of different size and power, detected on one occasion that each of two satellite shadows on the planet at the same time was attended by a faint duplicate of itself. Observation cited by the Rev. T. W. Webb, in his work *Celestial Objects*, p. 140, 2nd Edition.

In 1850 Mr. Lassell noted that the fourth satellite appeared markedly smaller than its shadow, and that the shadow was sen-

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sibly round. The observation was made with Mr. Lassell's 9-inch reflector of 9-feet focal length, and the planet was at the time near opposition. The connection of the position of the planet relatively to the earth, with the observed form of the satellite shadow, will become more evident in the latter portion of the present paper, supposing that the hypothesis therein advanced should prove worthy of attention after due examination of the observations next to be detailed.

September 19, 1870, 15^h 25^m to 16^h 55^m, G. M. T. Elongation of Earth, seen from *Jupiter* = 12° 58′.

Observing *Jupiter* with an 8-inch silver-on-glass reflector of 6-feet focus, a power of 520 measured diameters being in use, with which the planet and satellites were generally beautifully defined, I perceived that the shadow of the third satellite, which had entered the disk at the earlier epoch, was not round, but decidedly elongated in the direction of the parallel upon which it fell. The watch was kept up for an hour and a half, during which period the form of the shadow-spot underwent scarcely any sensible change. This form was, roughly speaking, that of a lozenge, the proportion of the principal diameters being as 1*. It fell on a narrow dark band. The satellites I, II, and III were for a time seen as neat, sharp, *round* disks, the last-mentioned displaying a dusky shading of irregular depth on its northern hemisphere. IV was irregular in outline.

October 3, 1870. Elongation of Earth, as seen from *Jupiter* = 11° 1′.

On this occasion the shadow of II on the planet was observed to be sensibly round, and blackest when definition was most steady. III and IV, which were close together, appeared very dissimilar, III being white, IV dusky, and, I believe, not round, but polygonal. II appeared beautifully round at the same time. Instrument, and, apparently the power used, identical with those employed on September 19.

November 10, 1870. Elongation of Earth, seen from *Jupiter* = 5° 19′.

The shadow of I appeared round, which form was maintained up to internal contact with the limb; it was afterwards seen bisected on the limb, and as a gradually diminishing segment of a circle. The shadow fell, I believe, on the equatoreal dusky region, but the obliquity of the line of sight was small.

Instrument used, the 8-in. reflector; but the power is not stated.

January 1, 1872. Elongation of Earth, as seen from *Jupiter*, or obliquity of line of sight = 3° 02′.

The shadow of the second satellite, which had accomplished two thirds of its passage, was several times seen as elongated in the

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* So in M.S., but ?. The author, being with the Transit Expedition at Rodriguez, has not corrected the proofs.—Ed.

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preceding and following direction, the longer axis being slightly oblique to the parallel on which it fell. It was situate just within the southern edge of the great equatoreal dusky belt, which was ochreish in tint and mottled with white. The planet was fairly defined with power 228 on the 7-in. speculum in use at the time. III and IV were occasionally very well shown with power 520. The observation was made under somewhat unfavourable circumstances, which were not, however, sufficiently adverse to warrant its exclusion from the series. The wind was very high, and the instrument occasionally considerably shaken.

January 8, 1872. Obliquity of line of sight = 1° 33′.

On this occasion the shadow-spot of II was seen for an instant as a round dot with the 7·2-in. reflector, armed with a power of 270 or 228, which power showed an immense amount of minute detail on the planet.

The character of the surface in the neighbourhood of the shadow-spot is not recorded, but it fell on the equatoreal dusky region. The observation was considered good, though brief. The planet is now near opposition.

March 6, 1872. Obliquity of line of sight = 9° 05′.

The shadow of IV in transit was observed under very favourable circumstances as to definition, etc., and three sketches of the form presented by it at $9^h\ 30^m$, $9^h\ 55^m$, and $10^h\ 0^m$, G.M.T. were made. The form recorded at the latest epoch was confirmed by another and independent observer using the same instrument. The shadow-spot was unmistakably elongated, in the direction of the belts, and was situated on a dusky band of irregular depth of tint.

The extreme diameters of the spot were variously estimated to be in the ratio 5 : 4 and 4 : 3. At $9^h\ 35^m$ it was noted that the north and south boundaries of the spot were sharply defined, while the preceding and following extremities were ill-defined. The disks of I, II, and IV were at times well shown, especially the two former. Power 408 on 7·2-in. reflector.

The form of the spot was carefully compared with that of the satellite's disks, which were beautifully round, and very sharp at times, and turning the head through a considerable angle from the vertical laterally, in order to guard against possible cylindricity of the crystalline lens. The observation was one of the most complete and satisfactory of the whole series.

It is to be observed that the obliquity of the line of sight was considerable, and that the shadow fell on a dusky region.

April 24, 1872. Obliquity of line of sight = 9° 27′.

The shadow of the first satellite was seen on a dark patch of belt 4 (Mr. Gledhill's notation). It was not round, and the

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major diameter was considered to be in the direction of the belt. The ratio of the extreme diameters was considered to be 1·2 or 1·3 to 1. The diameter of the shadow-spot was nearly equal to the diameter of the satellite itself, or perhaps more nearly to that of II. A penumbra was suspected at times with power 250.

The observation was considered good.

We note here that the obliquity of the line of sight is considerable; that the shadow was thrown on a dusky belt; and that the certain part of the observation is the elongation of the shadow-spot.

The instrument used was an exquisitely defining object-glass by Alvan Clark, of 7½-inches aperture, formerly belonging to Mr. Dawes, armed with powers of 250, and, I believe, 400, and equatoreally mounted in the observatory of W. Erck, Esq., Sherrington, Bray, Co. Dublin.

September 19, 1872, 16^h 40^m to 17^h 7^m G.M.T. Obliquity of line of sight = 6° 24′.

The shadow of the *third* satellite in transit was observed not to be circular in form At first it was seen to be winged both on the preceding and following sides; a little later the wing on the preceding side was the only one visible, and at 17^h 7^m the shadow-spot had resumed its doubly winged aspect, at which time the satellite (III) had entered on the planet to the extent of half its diameter.

About 16^h 55^m the north-preceding portion of the shadow had come into apparent contact with a bright spot, within the equatoreal dusky belt, which the shadow was traversing, and at that time the wing on the side of the contact appeared to be deviated slightly upwards, *i.e.*, southwards and away from the bright patch.

When the elongation of the spot was greatest the ratio of its extreme diameters was estimated carefully as 5 : 4.

I was compelled to defer the completion of the record until 7^h of the 20th September, when I added from recollection that the shadow appeared very slightly larger than the transiting satellite, which was perfectly round.

The obliquity of the line of sight was a medium one, and the shadow fell on a dusky ground. The instrument employed was a silver-on-glass reflector of 12-in. aperture, armed with a power of 408.

January 16, 1873. Obliquity of line of sight = 5° 32′.

The shadow of I, which probably fell within the limits of the equatoreal dusky belt, was carefully scrutinised without any defect of roundness being detected. A suspicion that there was a slight penumbra surrounding the shadow was entertained, but definition was at that time slightly diffused. The shadow was

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extremely minute, appearing perhaps smaller than II of the planet. Satellite I was on the planet, and invisible.

The record was not made until the 20th, when, however, my recollection was still perfectly clear.

The observation was considered good; and we have to note that the obliquity of the line of sight was below its mean value, and that the shadow fell on a portion of the surface which was neither bright nor dark.

Instrument used, the 12-in. reflector, power 400.

February 3, 1873. Obliquity of line of sight = 2° 19″.

The shadow of I was scrutinised when in transit with the 12-inch reflector, under powers of 238 and 409 diameters. No defect of roundness was discoverable, and its diameter appeared to be little more than half that of III, which was also sensibly circular.

Definition generally fluttering and furry, but quiet for a few seconds together at distant intervals. Observation considered good. The shadow fell on the equatoreal belt, which was at that time somewhat bright. The obliquity of the line of sight was small.

February 20, 1873. Obliquity of line of sight = 1° 01′.

The shadow of II in mid-transit was observed to be sensibly round, no irregularity of form being discoverable under powers of 238, 409, and 514; even, on comparing it with II, which was on the planet, close to the limb and appeared slightly larger than its shadow, the latter falling during its passage on different parts of the great dusky equatoreal belt and just within its northern limit.

Definition, at first fluttering, and only at moments distinct. became continuously good at the times of emersion of the satellite, With power 514 the *third* satellite appeared unequally shaded.

February 27, 1873. Obliquity of line of sight = 2° 41′.

The shadow of II was observed not to be perfectly round, like the satellite itself, but irregular in outline, and with power 409 it was less sharply defined than the satellites. I thought that there were some indications of a penumbra. The shadow-spot was situate, I believe, upon the dusky equatoreal zone.

The observation was considered good, and it is to be noted that the obliquity of the line of sight was small.

March 12, 1873. Obliquity of the line of sight = 5° 10′.

The shadow of I being in transit over the equatoreal dusky region, was scrutinised with an equatoreal reflector of 8-inches aperture, and power 280, without my being able to detect with certainty any difference between it and the second satellite in respect of form.

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A sketch of the form of a shading on the disk of I, detected while it was in transit, is appended. Fig. 1. *a*.

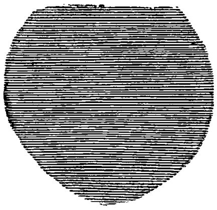

Fig. 1. a.

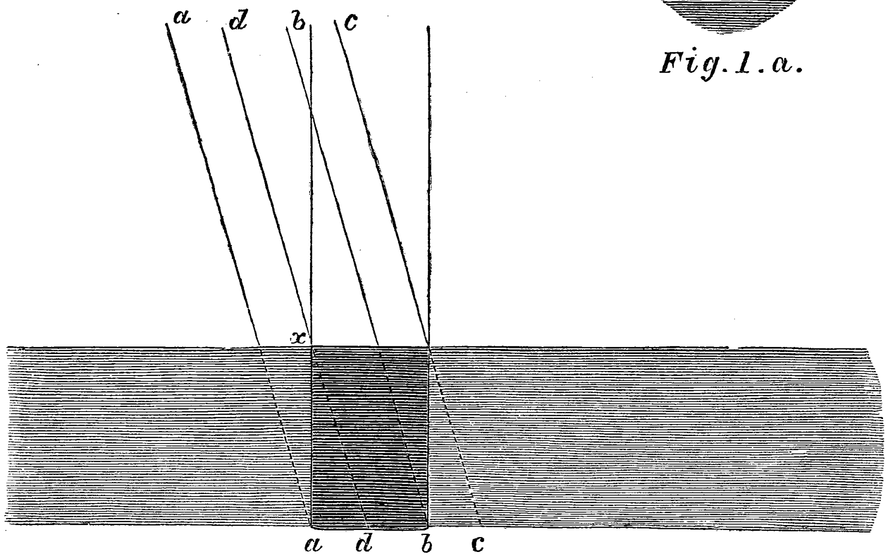

Fig. 1.

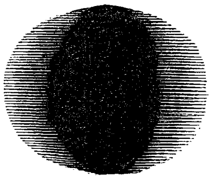

Fig. 2.

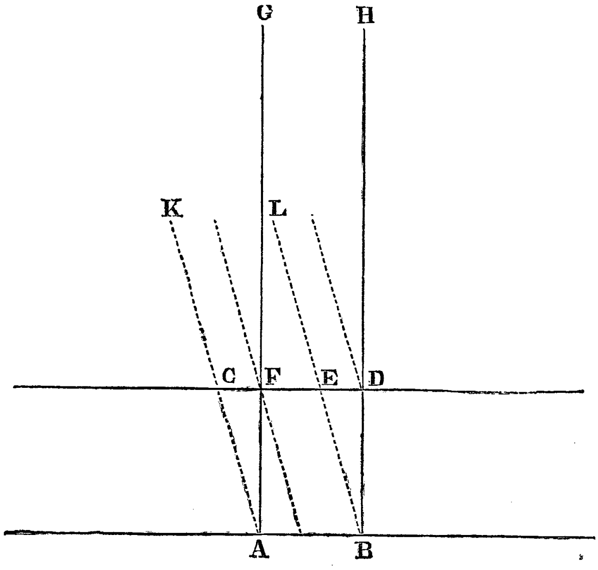

Fig. 3.

The observation was considered good. The obliquity of the line of sight was approaching its mean value; but it is to be observed that the shadow fell on a portion of the surface of the

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dusky equatoreal belt, which was at this time brighter than the medium tint.

April 8, 1873. Obliquity of the line of sight = 9° 03′.

The shadow of III was observed in transit, and a sketch made about 8^h 15^m. It was elongated in the direction of its motion, but not much so, the projection on the preceding side being visible only when definition was at its best, under power 514 on the 12-inch reflector. The shadow had completed about four-fifths of its passage, and fell very near to the northern edge of the dark belt No. 3 Gledhill. The shadow was perfectly black over the greater part of its area. There was a slight protuberance on the side, much smaller than that on the opposite portion, which latter faded rapidly into the background of the dusky belt.

At times I failed to see the above-mentioned wings of the shadow, especially that on the following side; but these variations appeared to be unconnected with variations in the tint of the regions traversed by the shadow, and to be due solely to the occasional undulations of the air which at intervals distorted the disks of the satellites. No trace of true penumbra was seen, the north and south limbs of the shadow appearing free from any indistinctness. The two principal diameters were estimated to be in the ratio of 5 : 4 at the utmost, and the shadow was considered to be very slightly smaller than III outside the disk, which was exquisitely defined and unequally shaded.

The observation was given a high weight, the circumstances being unusually good. The line of sight had attained a considerable obliquity, and the region traversed by the shadow was of medium tint.

April 12, 1873, 8^h 45^m to 8^h 55^m, G.M.T. Obliquity of line of sight = 9° 25′.

The shadow of IV was observed to be elongated in the preceding and following direction, and the ratio of the axes was estimated at 5 : 4 or 4 : 3. It was not perfectly sharp, and appeared slightly larger than IV itself outside the disk of its primary. IV itself appeared to be somewhat softly defined, and slightly oval in the same direction as its shadow, I, which was near it, being perfectly sharp and round, under the same power, and at the same time. The shadow fell on a slightly shaded space within the bright band separating the dusky belts Nos. 2 and 3 in Mr. Gledhill's nomenclature; apparently a knot or projection from the lower or northern boundary of No. 3.

About 9^h 25^m IV appeared nearly, but not quite circular, the deficiency conceived to exist being situate on the preceding or north-preceding portion of the satellite's disk, and very small in amount. The shadow still elongated, and to about the same extent as at first. At 9^h 55^m the shadow was found to be on a narrow oblique dusky belt connecting the dusky belts 2 and 3

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mentioned above, and still elliptic in form, in the same direction as before, the ratio of the axes being now about 5 : 4. Its diameter was very nearly equal to that of IV. The observation, which was made with the 12-inch reflector, was given full weight. The power used was not recorded, but was in all probability either 409 or 514, as these powers were almost invariably employed for scrutinising the satellites and their shadows.

The obliquity of the line of sight was still considerable, and the shadow traversed a dusky region.

May 6, 1873. $10^h \pm$ G.M.T. Obliquity of line of sight = 10° 45′.

The shadow of I a little past mid-transit appeared elongated, the ratio of the axes being by estimation as great as 3 : 2, and the minor axis very slightly less than that of I outside the disk of the planet. This was the result of a tolerably good view lasting only a few seconds. The shadow did not appear black, definition being soft. It fell in a very dark patch near to the northern edge of the equatoreal dusky belt.

Next day I recorded that III appeared elongated in the same direction as the shadow, and that I, as I thought, did *not* present this aspect.

On this occasion the circumstances were rather unfavourable, and less weight is therefore to be attached to the observations made. The obliquity of the line of sight was considerable, and the elongation of the shadow seems to have been great.

December 19, 1873. Obliquity of line of sight = 10° 25′.

The shadow of IV in transit was observed when it had completed about three-fourths of its passage, and was at times well seen with a power of 400 on the 12-inch reflector. It did not appear to be circular, my impression being that it was slightly lozenge-shaped, or irregularly elliptical, and that the ratio of the extreme diameters was 6 : 5. The form of the shadow certainly seemed to differ markedly from that of III, which was shown by the same power as a neat circular disk. IV I thought to be elliptic, the major axis lying nearly in the preceding and following direction. The major axis of the shadow-spot was considered to be parallel to the belts.

It did not appear perfectly black, and its diameter considerably exceeded that of IV, which was some distance from the planet.

The shadow fell upon the northern polar shading, which was nearly uniform in tint and light grey tinged with blue. The shadow was not so sharply defined as the limb of the planet, or the disk of III.

I turned my head laterally while observing, through 30° about the emergent pencil as axis, without perceiving any change in the form of the shadow. There was no distortion of the disks of the satellites.

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The colour of the equatoreal region, a faint ochreish yellow, contrasted finely with the bluish grey of the north polar cap. The observation was satisfactory though brief, and the comparisons are considered reliable, but the deviation of the shadow-spot from a circular form was so slight that I could not assure myself of its precise configuration. The obliquity of the line of sight is here large; but it is to be noted that the region traversed by the shadow-spot, though dusky, probably differs in its nature from the equatoreal zones within which the paths of the shadow were on former occasions comprised.

May 19, 1874. Obliquity of line of sight = 9° 50′.

The shadow of IV being on the disk of *Jupiter* at G.M.T. was carefully scrutinised by Mr. Erck and myself with Mr. Erck's 7½-inch Equatoreal armed with a power of 250, and compared as to form with the satellite's disks, which last were perfectly free from distortion when best seen, which was not the case with the shadow. The shadow was strongly elliptical, and the ratio of the axes was estimated to be 3 : 2.

The minor axis did not, I believe, differ much in length from the diameter of the satellite (IV).

The major axis was inclined to a parallel of Jovian latitude by 15° or 20°. Both the observers agreed as to this point.

The shadow was situate on the grey northern cap during the whole of the observation.

The extremities of the major axis appeared to be much more nebulous than any other portion of the outline of the shadow.

The dusky equatoreal zone had a strong coppery tinge, and the limb of the planet furthest from the Sun was decidedly ill-defined, the terminator on the E. side being within the Jovian hemisphere next the Earth.

The observation was exceptionally good, and possesses the additional confirmation of the independent testimony of an experienced observer.

The obliquity of the line of sight was considerable, and the region on which the shadow fell was dusky in tint.

At the commencement of the next division of the subject, namely, the connection of the foregoing observations with a hypothesis put forward as early as April 1871, to explain the appearances detected, I will call attention to the apparent dependence of their variations upon the relative positions of the Sun, the Earth, and *Jupiter*; the elongated form of the shadow-spots being visible, with one apparently unimportant exception, only when *Jupiter* is near quadrature, or, in other words, when the line joining *Jupiter* and the Sun attains its maximum inclination to the line connecting *Jupiter* and the Earth.

This dependence will become more evident if the recorded observations are arranged in a tabular form in juxtaposition

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with the corresponding values of the angle included between the visual direction and the axis of the shadow cone or *Jupiter's* radius vector for the epoch of observation, which angle is that expressing the obliquity of the line of sight. See headings to observations in the former part of this paper.

Tabular Summary of Observations.

Table I.

Date.	Sat.	Form of Sh.	Obliquity. ° '	Nature of Surface.	Instrument.	Weight.
1870 Sept. 19	III	Elong.	12 58	Dark belt	8-in. reflector	Obs. good
Oct. 3	II	Round	11 01	Bright belt	,, ,,	,, ,,
Nov. 10	I	Round	5 19	Dusky eq. belt	,, ,,	,, ,,
1872 Jan. 1	II	Elong.	3 02	Equ. dark belt	7-in. reflector	Obs. defective
Jan. 8	II	Round	1 33	Probly. as last	,, ,,	,, good
Mar. 6	IV	Elong.	9 05	Equ. dark belt	,, ,,	,, ,,
Apr. 24	I	Elong.	9 27	Equat. dark	7½-in. object-glass by Alvan Clark	,, ,,
Sept. 19	III	Elong.	6 24	Equat. dusky	12-in. reflector	,, ,,
1873 Jan. 16	I	Round	5 32	Probably equa. dusky belt	,, ,,	,, ,,
Feb. 3	I	Round	2 19	Probably same region	,, ,,	,, ,,
Feb. 20	II	Round	1 01	Same region	,, ,,	,, ,,
Feb. 27	II	Irreg. not Elong.	2 41	,, probably	,, ,,	,, ,,
Mar. 12	I	Round	5 10	Equat. d. belt	8-in. reflector	,, ,,
Apr. 8	III	Elong.	9 03	,,	12-in. ,,	,, ,,
Apr. 12	IV	Elong.	9 25	Shaded space in bright belt	,,	,, ,,
May 6	I	Elong.	10 45	Very dark part of eqtl. d. belt	,, ,,	Pretty good
Dec. 19	IV	Elong.	10 25	Grey n. cap.	,, ,,	Good
1874 May 19	IV	Elong.	9 50	,, ,,	7½-in. Alvan Clark	,,

On comparing the forms of the shadows with the corresponding obliquities, it will be at once evident that a small obliquity is, with one exception, and that the most doubtful of the series of observations (Table I, 1872, January 1), accompanied by a circular form of shadow.

The converse cannot be so broadly stated, two exceptions, observed under favourable circumstances, presenting themselves (Table I, 1870, October 3, and 1870, November 10?), differing from that just mentioned in that they are readily explicable on the hypo-

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thesis put forward in the present paper, which assumes that the variations of brightness on the disk of *Jupiter* are due to the greater or less accumulation of masses of cloud, separately invisible and distributed through an extremely transparent atmosphere of enormous depth.

If a shadow of a satellite fall upon such an atmosphere, all the cumulus clouds within the shadow will be rendered dark and invisible.

If the shadow-spot be viewed when the earth is near the axis of the shadow cone, the part of the atmosphere in shadow will appear as a tolerably well-defined dark, almost circular spot.

On the other hand, if the shadow be viewed in a direction somewhat inclined to its axis, along the line *aa* or *cc* (Fig. 1) the clouds in the immediate neighbourhood of either of those lines will all be fully illuminated, and the brightness of the surface at that point will be sensibly the same with that of the surface outside those lines.

Again, the space between *bb* and *dd* falls within the unilluminated region, and will therefore return no light to the eye. This portion will therefore appear sensibly black.

And it is evident, from a consideration of the figure, that the darkness will gradually shade off from *dd* to *aa*, and from *bb* to *cc*. Now this is precisely the appearance presented when the observer was in a situation sufficiently removed from the axis of the shadow, and when the portion of *Jupiter* on which the shadow fell was dusky; in other words, when the clouds were sufficiently scattered to allow of our seeing to the lower strata of the immense atmosphere of *Jupiter*.

The form of the darkest portion of the shadow-spot seen from a distance will manifestly be lenticular, being contained between the projected outlines of the circular segments of the upper and lower sections of the shadow at the level *x* and at the level *ab*.

The apparent form of the shadow seen by an observer so placed will closely resemble that shown in Fig. 2, where the line *ac* indicates the plane of the section of sketch Fig. 1.

In the foregoing paragraphs it has been assumed, in order to avoid unnecesary complication, that the penumbræ of the shadows due to the sensible angular diameter of the Sun are imperceptible.

Geometrically this can never be the case, but the breadth of the penumbra is so small that its only visible effect would be to render the upper and lower edges of the dark spot (Fig. 2) very slightly less defined.

To this hypothesis it may be objected, that it is not immediately evident why it should be preferred to another which seems to have certain points in its favour, namely, that which supposes *Jupiter* to shine merely as a phosphorescent body, by the solar light.

This hypothesis demands the additional assumption that the surface does not acquire or lose its brilliancy at once when the Sun's light falls on it or is withdrawn.

By making appropriate suppositions as to the retentiveness of

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light on the part of the atmosphere, it is evident that the aspect of the shadow-spot may be supposed to vary from that of a sharply defined dark patch corresponding in form to the section of the shadow cone at the level of the obscured region, through the intermediate stages of a continually diminishing black patch of lenticular form to the final aspect of a barely discernible shade travelling over the surface of the planet, the wings on the preceding and following sides, where the light is not acting fully, having coalesced.

This hypothesis fails to meet the facts in one very important respect, for, according to it, the winged aspect of the shadow ought to be presented at every transit, irrespective of the position of the observer. This is not the case according to the observations cited above, and we may therefore consider the original supposition as the more probable one.

We are by it led to the conclusion, that the degree of elongation visible will depend on these three conditions: the obliquity of the line of sight, the depth of the clouds stratum, and the degree of aggregation of the floating cumuli. This is at once evident on inspection of Fig. 1.

The mode of deducing the depth of the atmosphere from the data now in our possession is perhaps most readily shown by an outline reproduction of Fig. 1 in Fig. 3, where CD is the upper limit of the cloud stratum, AB the lower limit of visible shadow penetration; and where GA and HB are the bounding lines of the shadow cone lying in the plane bisecting the shadow-spot at its longest diameter, and KA, EB, LD are portions of lines drawn in the same plane from the observer's eye to the points A, B, D, and are sensibly parallel to one another, as also are the lines FD, AB; GN, HB respectively.

Therefore CE=AB=FD=diameter of shadow cone=minor diameter of shadow-spot.

CF is therefore the difference between the greatest and least diameters of the shadow-spot.

The ratio CD : FD being known from the observations, and also the approximate length of FD in miles as well as the angle CAF or the obliquity, we have at once

$$\begin{aligned}\text{Depth AF in miles} &= \text{CF} \cdot \cot \text{CAF} \\ &= \frac{\text{CD}-\text{FD}}{\text{FD}} \times \text{No. miles in FD} \times \cot\ \text{CAF}.\end{aligned}$$

Applying this formula to the observations, we deduce the following results, embodied in Table II, in which the depths of shadow penetration vary between 3,200 and 9,200 miles.

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TABLE II.

Date.	Sat.	Diam of Sh. assumed. Miles.	$\frac{CD-FD}{FD}$	Depth deduced.	Weight attributed.	Remarks.
1870 Sept. 19	III	3300	0·4	5700	Obs. good	Elongation deduced from sketch
1872 March 6	IV	2800	0·3	5200	„ „	
April 24	I	2100	0·25	3200	„ „	
Sept. 29	III	3500	0·25	7800	„ „	
1873 April 8	III	3300	0·2	4000	„ „	
April 12	IV	2800	0·3	4200	„ „	
May 6	I	2100	0·5	5500	„ tolerable	Air unsteady
Dec. 19	IV	3500	0·2	3800	„ good	Amount of elongation doubtful
1874 May 12	IV	3200	0·5	9200	„ very good	Incidence very oblique.

The exceptionally large result just quoted is apparently due to the low angle of incidence at which the shadow met the surface of the cloud region; falling, as it did, very near to the pole of the planet, and therefore probably traversing a much greater extent of atmosphere than if it had been thrown on the central regions of the planet.

The numbers given in Table II, column 5, are probably less than they ought to be; the ratio $\frac{CD}{FD}$ having been estimated too low on account of the gradual fading of the elongated shadow-spot into the tint of the surface in the immediate neighbourhood of the extremities of its major axis; which renders it impossible to say definitely where it terminates.

The estimation of the ratio is injuriously affected also by the extreme minuteness of the angle under which the spot is seen, which probably never exceeds $1''\cdot75$. In determining the forms of such minute objects the eye is probably more trustworthy than the micrometer, that is, if it has received a careful training in the work required to be done.

It is plain that the well-known suggestion which was made soon after the discovery of the low mean specific gravity of *Jupiter*, that within an atmosphere of great depth there existed a nucleus approaching in density to that of the interior planets, is, in part, an anticipation of that put forward in the present memoir, and, by its reasonableness, has commended itself to many writers on planetary physics; but the additions now made to it, especially the assumption of the transparency of the atmosphere, perfect enough to permit us to trace a shadow through it for nearly 10,000 miles, is sufficiently startling to induce great hesitation in accepting the modified hypothesis. One agreement between the results of this hypothesis and observation may be pointed out.

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(1.) It has long been known that the limb of *Jupiter* is much less brilliant than the centre of the disk, and that the brightness rapidly increases with the distance from the limb:

(2.) also that the apparent orbital motions of the satellites when undergoing or emerging from occultation are unaffected by refraction.

(3.) We have lately been made aware that the atmosphere of *Jupiter* probably contains a considerable proportion of aqueous vapour mingled with other vapours as yet unknown.

(2) and (3) taken together render it likely that the selective absorption observed takes place below the upper cloud stratum, and amongst the separate clouds floating in the atmosphere, somewhat in the same manner as the selective absorption producing the Fraunhofer lines appears to have its seat among the granules of the solar photosphere, as far as many of those lines are concerned.

The Jovian clouds may rise almost to the upper limits of the sensibly refracting atmosphere, and may be somewhat scattered, so that in the neighbourhood of the limb the visual ray may here and there pass amongst them freely.

The number of such openings will evidently increase rapidly toward the limb, which will consequently diminish in brightness with equal rapidity, the dark background of space becoming visible in an augmented ratio.

The solar atmospheric surroundings present the only known instance of a gaseous envelope of a depth and transparency equalling or rather far surpassing those attributed in this paper to the atmosphere of *Jupiter*.

But the temperatures at which the respective atmospheres are maintained in the case of the two bodies probably differ enormously, and the density of the lower stratum of the Jovian atmosphere must consequently be extremely great, if its depth approaches even the least of those assigned to it in Table II.

This probability constitutes a difficulty, and a great one, in the way of accepting Table II, col. 5; which further observation and experiment may, it is hoped, remove.

One argument in favour of the supposed constitution may, perhaps, be drawn from certain observations made under favourable circumstances by Messrs. Schwabe and Jacob many years since, and more recently by the Earl of Rosse, to the effect that the cloudy masses of the Jovian atmosphere are, occasionally at least, broken up into fine filaments or elongated particles, especially in the neighbourhood of the equator. I may, perhaps, be permitted to add, that I have repeatedly received a similar impression when working with different instruments of apertures (effective) varying from 7 to 12 inches, and using high powers; the equatoreal region alone presenting this appearance. The breadth of the fine streaks referred to in the last sentence must have been less than $0''\cdot25$.

Here I leave the subject in the hands of far abler observers

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than myself, by whose verdict the question will ultimately be decided, and regretting that my own opportunities of collecting evidence have been so few and far between.

Loughlingstown, Co. Dublin.

Letter from an Officer in the Merchant Navy on the Application of Corrections for Change of Temperature to the Rates of two Chronometers during a voyage from Liverpool to Calcutta.

(*Communicated by Mr. Hartnup.*)

During my last voyage from Liverpool to Calcutta, on board the ship "Tenasserim," I had an opportunity, through the kindness of the Commander, Captain T. C. Potts, of testing the practical value of your method of finding the rate of a chronometer at sea by the application of corrections due to change of temperature.

In 1873 I obtained a copy of your Report to the Marine Committee of the Mersey Docks and Harbour Board for the preceding year, in which you have given examples of the method of making the necessary calculations, and I have followed the instructions there given. The two chronometers used on the voyage were named "J. Basnett & Son, No. 713," and "Thomas Blundel, No. 209." The data from which I made my calculations I obtained from two certificates given by you at the Bidston Observatory in September 1871, from which I obtained the following results:—

No. 209.

Rate in $55^\circ = -5^\circ{\cdot}58\ r$
" $70^\circ = -4^\circ{\cdot}00\ r'$
" $85^\circ = -2^\circ{\cdot}70\ r''$

$r - r' = -1^{s}{\cdot}58 = d$
$r' - r'' = -1^{s}{\cdot}30 = d'$
$d - d' = -0^{s}{\cdot}28$
$d + d' = -2^{s}{\cdot}88;$

$$C = \frac{2(d-d')}{30^2} = \frac{-0{\cdot}56}{900} = -{\cdot}00062;$$

$$T - 70 = \frac{d+d'}{C \times 60} = \frac{-2{\cdot}88}{-0{\cdot}0372} = +77{\cdot}4;$$

$$T = 70 + 77{\cdot}4 = 147{\cdot}4;$$

$$R = r' - (T-70)\frac{d+d'}{60} = -4{\cdot}00 + 77{\cdot}4 \times {\cdot}048 = -0{\cdot}28.$$